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WESTERN HEMLOCK.

Tsuga heterophylla (Raf.) Sargent.

One of the most abundant conifers of the Pacific Northwest is western hemlock, yet up to the present time it is not a popular species commercially; indeed, in proportion to its abundance, it is scarcely being utilized at all. The wood of eastern hemlock, *Tsuga canadensis* (Linn.) Carr., has several qualities that make it undesirable for many purposes, and western hemlock has suffered in the market from the prejudices which prevailed against its eastern relative. In reality its wood is much superior to the eastern species, and for many purposes it is very desirable. It is used chiefly for general construction work, but is also valuable for flooring, siding, and panel work. It is suitable for paper pulp, and it is likely that western hemlock will be largely used for pulp in the future, with the exhaustion of the eastern pulp woods. Its bark is rich in tannin and contains from 10 to 20 per cent, with an average of about 15 per cent. It is used locally now, and should become, in the near future, a large source of tanning extract.

RANGE AND OCCURRENCE.

Western hemlock grows in the Pacific coast forests from Cape Puget on the western side of Prince William Sound south along the coast ranges to Marin County, Cal., and extends eastward in Oregon and southern Washington as far as the crest of the Cascade Mountains; across northern Washington and southern British Columbia, however, it goes as far east as the western spurs of the Rocky Mountains in northern Idaho and northwestern Montana. It is generally restricted to the humid part of its geographic range, and therefore is

most abundant on the slopes facing the ocean, and absent from the dry plateau region east of the Cascades in Oregon, Washington, and British Columbia. In California it is rare south of Humboldt County, and nowhere in the State is it commercially important.

The altitudinal range of western hemlock is from sea level up to 7,000 feet. In Alaska it goes practically up to timber line at 3,000 feet, but it ascends to higher and higher elevations in the more southerly and drier part of its range. In northern Idaho, for example, it commonly ranges from 2,000 to 5,000 feet. It is a moisture-loving tree and grows, therefore, in situations where either the soil or the atmospheric moisture is high. In the coast mountains or high up on the Cascades, where the precipitation is heavy, western hemlock grows alike on the slopes and in the bottoms and is the most abundant tree, but in the foothills and valleys, where the precipitation is less, it is mainly confined to moist draws and bottoms. In northern Idaho and western Montana it grows only on cool, moist, north slopes and flats.

CLIMATE.

The climatic conditions within the range of western hemlock are generally favorable to tree growth; there is heavy precipitation, high humidity, a long growing season, no extreme temperatures, and a fairly uniform climate from year to year. There is, however, a decided contrast between the climate at the northern and the southern extension of its range, and between that in the foothills and on the high mountains, which indicates that western hemlock is not especially fastidious in its climatic requirements. This is further shown by the fact that the annual precipitation within its range varies from 30 to 130 inches. It endures temperature below zero (F.) without injury. The one essential requirement seems to be an abundant supply of atmospheric humidity; this is indicated by its preference for cool, moist, north slopes and valley bottoms. The finest hemlock in Washington grows at an altitude of from 2,000 to 3,500 feet on the western foothills of Mount Rainier, where the annual precipitation is more than 70 inches and where snow lies half the year.

ASSOCIATED SPECIES.

Western hemlock grows in pure or in mixed stands, and in the mature forest usually yields from 50,000 to 125,000 board feet per acre. In the coast mountains in the northern part of its range, where conditions are ideal for its best development, it forms fairly pure stands of great density over large areas. In the Cascade Mountains pure stands are less common. Douglas-fir, western red cedar, and lowland fir are associated with it to a greater or less extent in nearly every part of its range. Toward the north Sitka spruce is its char-

acteristic associate; on the upper slopes of the Cascades amabilis fir, noble fir, mountain hemlock, and yellow cypress are commonly found with it; and in northeastern Washington, Idaho, and western Montana western white pine, western larch, and to some extent Engelmann spruce enter into the mixture.

In the heavy Douglas fir forests of western Washington and Oregon western hemlock is common as an understory to the larger Douglas fir. In such a forest the Douglas fir eventually becomes mature and dies, and the hemlock, together with some western red cedar and lowland fir—all tolerant species—crowds up and takes its place, thereby transforming the forest type from one of Douglas fir to one of hemlock. A similar process takes place in the western white pine forests of northern Idaho and northwestern Montana, where western white pine and western larch are gradually replaced by the hemlock. This transformation of one forest type into another is common in both regions and presents an important forest problem.

HABIT.

Western hemlock is not so large a tree as its usual associates, Douglas fir, Sitka spruce, western red cedar, western white pine, and western larch. Its usual mature size in the forests of the coast and Cascade Mountains is from 150 to 200 feet in height and from 3 to 4 feet in diameter; in the Idaho region it is from 2 to 3 feet in diameter and approximately 100 feet high. Exceptionally large trees reach 250 feet in height and 8 feet in diameter. The trunk is regular and cylindrical, except at the very base, where it often has wide buttresses. The crown, composed of small, pendulous branches, is narrow and pyramidal and usually extends rather far down the tree. The root system is very shallow and the tree is consequently susceptible to damage from high winds and from ground fires.

SOIL AND MOISTURE.

Abundant atmospheric and soil moisture are essential for this species. It does best, therefore, in bottom lands, draws, and along watercourses, or in regions of high precipitation on well-watered slopes. With an abundance of atmospheric and soil moisture, as in the coastal strip, it thrives on poor soil and on any exposure, and is found in all kinds of ground from mucky lowland soil to rocky hillsides. Good, deep, porous soils are, however, necessary for its best growth.

TOLERANCE.

Western hemlock is shade enduring and is usually considered to be more tolerant than any of its coniferous associates, with the exception of western red cedar. Throughout its life it can endure

heavy shade, so that it can survive either in the understory of a stand of more rapid-growing species, such as Douglas fir or western white pine, or as the dominant species in very dense stands with various tolerant conifers. Under heavy shade its growth is slow, but with the admittance of light it quickens its growth and makes a remarkable recovery from suppression.

GROWTH AND LONGEVITY.

The rate of growth, therefore, depends very largely upon the amount of space and light that the tree has. The growth of trees under heavy cover is exceedingly slow, while that of dominant trees compares favorably with its rapid-growing associate, Douglas fir. The following table shows a striking contrast between the average rate of growth of old trees which have developed in the shade of Douglas fir and of second-growth trees which have been free from suppression:

Age.	Diameter.		Height.	
	Second growth.	Old growth.	Second growth.	Old growth.
Years.	*Inches.*	*Inches.*	*Feet.*	*Feet.*
50.....	12.7	2.0	96	38
100.....	17.1	10.0	132	69
200.....	.....	22.2	.....	134
300.....	.....	34.8	.....	192

These great differences in the rates of growth in the two types of forest show that, with favorable light conditions, western hemlock is rapid growing and that with unfavorable conditions it is exceedingly slow growing.

Though not so long lived as some of its associates, exceptional specimens probably reach an age of 500 years.

SUSCEPTIBILITY TO INJURY.

Western hemlock is susceptible to various injuries. It is sensitive to fire and suffers heavy fire damage, partly because of its thin bark and partly because of its superficial root habit. It is often killed out of a stand by even light surface fires. Frequently the vegetable litter and the decayed logs on top of which hemlocks are growing are burned out, so that the trees are toppled over. Its superficial root habit also makes western hemlock susceptible to wind storms, and trees in exposed situations, such as cull trees left in logging operations, are likely to be overthrown by the wind.

There are many fungi and insects which infest the tree and seriously damage it. It is estimated that in western Washington and Oregon nearly one-fourth of the hemlocks under 3 feet in diameter

are infested with some kind of fungus, and an even greater proportion of the larger trees are diseased. In the Idaho region the proportion of infected trees varies from 40 to 100 per cent. Western hemlock wood, however, is reported to be immune from damage by white ants in the Philippine Islands; if this immunity is found to exist everywhere the lumber should be of great value in the Tropics.

REPRODUCTION.

Western hemlock is a very prolific seeder, and open-grown trees begin to bear at from 25 to 30 years. Every year some trees in the stand bear seed and heavy crops are borne at frequent intervals. The seeds are light and are widely disseminated by the wind. They germinate readily on moist seed beds, particularly on vegetable litter and decaying wood. The seedlings of hemlock, more than those of any of its associated species, seem to prefer to start on the top of disintegrating logs, and saplings of considerable size are frequent in such situations, though reproduction on mineral soil, if moist, is not uncommon. The young growth is extremely tolerant of shade, and a dense carpet of hemlock seedlings is not uncommon in very heavy woods. Shade is not essential, however, and reproduction takes place also in the open, provided moisture conditions are right. Bare, burned-over land is, however, not suitable for hemlock reproduction, in which respect hemlock is exactly opposite to Douglas fir.

MANAGEMENT.

At present western hemlock is not valuable enough to deserve first consideration in the management of the forests of the Pacific Northwest. It should be considered as a secondary species, which must give place to better ones—Douglas fir, western white pine, western red cedar, and noble fir—in cutting and regenerating the forest in which it grows. Hemlock in mixture with Douglas fir, and comprising 30 per cent or less of the stand, as it commonly does, should be cut clean, the usual practice in logging. Seed trees of Douglas fir should be left, however, so that the succeeding stand may consist, to as large an extent as possible, of Douglas fir. In short, Douglas fir should be favored in preference to hemlock wherever such a plan is feasible. A slight admixture of hemlock as an understory in a fully stocked Douglas fir stand is not undesirable, for it may actually increase the total yield per acre, but no special effort will be needed to secure this mixture.

Western hemlock in mixture with western white pine in northern Idaho should also be considered a secondary species, and the pine should be favored in management at the expense of the hemlock. In the western white pine region, moreover, western hemlock is so

defective that the sooner it can be eliminated from the stand the better. Here western red cedar, rather than western hemlock, should be encouraged to form an understory under the dominant white pine.

In the coast range region western hemlock often forms a large proportion of the stand, and it is evident that a clean-cutting system would not promote a second crop of pure Douglas fir. Under these conditions it will probably be best in cutting the forest to spare the younger trees as far as possible, so that they may be left as the basis for the next crop; in other words, to manage the forest for tolerant species such as western hemlock, Sitka spruce, and western red cedar, rather than for the intolerant Douglas fir.

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